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MITIGATING THE EFFECTS OF INOPERABLE SERVO READERS
USED FOR DATA TRACK POSITIONING ON TAPE DRIVES

RELATED APPLICATIONS

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The present application is related by subject matter to commonly assigned, co-pending U.S. Patent Application Serial No. 09/751,575 (Attorney Docket No. 00-085-TAP) entitled "USING COMPONENT POSITION ERROR SIGNALS (PES) TO

10   MEASURE TAPE DISTORTION", filed on December 29, 2000, and hereby incorporated by reference.

BACKGROUND OF THE INVENTION

15   **1.   Technical Field:**

The present invention relates generally to an improved data recording system, and in particular, but not exclusively, to a system and method for mitigating the effects of inoperable servo readers used for data

20   track positioning on tape drives.

2.   Description of Related Art:

Tape drives are peripheral mass storage devices often used to archive data on tapes for later access.

25   Tape drives are also used as random access devices in data storage applications where the cost of storage might be important and access time is of less significance. For example, many banks and financial institutions, insurance companies, and government agencies may use tape

30   drives with applications regarding clients, accounts, patients, and other items of interest. In other

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applications, huge amounts of data are stored directly on tape for later retrieval and analysis.

In accessing data on a tape, a read or write head in a tape drive is positioned over one or more tracks on the
5   tape. Typically, two or more servo tracks on the tape are used for aligning the read or write head to the tracks containing the data. For example, servo control information can be located in the servo tracks. This servo control information can be a repeating pattern of
10 magnetic flux transitions. Alternatively, optical servo tracks may be found on the tape. Servo readers read the servo control information from the servo tracks on the tape, and generate position signals used to control the positions of associated data read and write heads over
15 tracks containing the data.

If a read or write head drifts from an optimal position relative to a track on the tape, a servo reader generates an error signal. The error signal increases as the read or write head drifts further from the optimal
20 location relative to the data on the track. If the read or write head drifts too far relative to the data on the track, errors and data recovery problems occur in accessing the tape. Existing systems adjust the position of the read or write head, or the position of the tape
25 relative to the read or write head, to minimize the error signal generated by the servo reader during access of the tape.

Evidence indicates that, over time, tape dimensions are distorted over the length of the tape. In addition,
30 such tape distortion can worsen with a combination of

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time, temperature, and use. As such, significant
problems result from tape distortion. For example, the
data tracks on a tape can shift position relative to the
data read and write heads, resulting in the loss or
5   overwriting of data. Also, distorted servo tracks can
degrade the ability of the tape servo system to acquire
and follow the servo tracks, resulting in degraded
performance. Notably, these tape distortion problems are
exacerbated if a servo reader becomes inoperable. The
10   temporary or long term loss of a servo reader compromises
the quality of the position error information received by
the tape servo system, which in turn, compromises the
effectiveness of the servo system's track alignment or
track following ability. Ultimately, the combined
15   problem of tape distortion and compromised track
alignment or track following ability significantly
increases the probability of data loss.

        For example, assume (for illustrative purposes) that
a conventional read/write head assembly includes two
20   operable servo readers. The head assembly may contain a
columnar arrangement of elements including, for example,
an upper servo reader, a lower servo reader, and a
plurality of data read/write elements located between the
servo readers. With two servo readers, the track
25   following operation for a distorted tape is typically a
compromise. One servo reader is positioned "high"
relative to a servo pattern being tracked, and the other
servo reader is positioned "low". As a compromise, the
two servo readers "split the difference" for the track

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following error, in order to minimize the tracking
offsets for the data read and write elements involved.

    If one of the servo readers becomes inoperable, the
servo system cannot position the read/write head assembly
5   in an optimal, compromise location. Consequently, the
data read and write elements located near the operating
servo reader typically follow their respective data
tracks closely. However, the read/write data elements
located farther away from the operating servo reader
10 typically have tracking offsets that substantially
reflect the distortion of the tape.

    For example, each servo reader tracks a respective
servo stripe on the tape. Using two servo readers, if
the amount of tape distortion between the two servo
15 stripes is expressed as a distance value, N, then the
optimal position of the read/write head assembly is with
one servo reader located at +N/2 and the other servo
reader located at -N/2. In this case, the data
read/write elements located midway between the servo
20 readers track very well with little or no offset.
However, the data read/write elements nearest the servo
readers can be misaligned with an offset as large as N/2.
Under these conditions, and now assuming that the lower
servo reader has failed, the upper servo reader can still
25 track its servo pattern very well with little or no
offset. Also, the data read/write elements located
nearest the upper servo reader can track very well.
However, the data read/write elements located nearest the
lower, inoperable servo reader are misaligned by a factor
30 of N. As such, if one of two servo readers fails, and a

distorted tape is also involved, then the data read/write elements can be misaligned with an offset difference factor as high as 2.

5   Therefore, it would be desirable to have a method and system for mitigating the effects of inoperable servo readers used for data track positioning on tape drives.

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SUMMARY OF THE INVENTION

The present invention provides a method, system and
program for mitigating the effects of one or more
5   inoperable servo readers used for data track positioning
on a tape drive. A track following servo system can
compensate for an inoperable servo reader by collecting
and measuring tape distortion information from the tape
involved. The track following servo system can quantify
10   the tape distortion information and produce a tracking
offset value. The track following servo system can then
position an operable servo reader over the tape with the
compensating offset value applied.

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BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The

5 invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

10   **Figure 1** depicts a diagram illustrating a tape drive system in which the present invention may be implemented;

      Figures 2A-2C depict related schematic diagrams of tapes and servo tracks that may be used to illustrate principles of the present invention;

15   **Figures 3A-3D** depict related schematic diagrams illustrating tapes and servo tracks in accordance with a preferred embodiment of the present invention;

      Figure 4 depicts a schematic diagram illustrating servo position errors due to displacement of servo tracks

20 in accordance with a preferred embodiment of the present invention;

      Figure 5 depicts a schematic diagram illustrating compressive and tangential forces on a tape wrapped onto two spools in accordance with the present invention; and

25   **Figure 6** depicts a schematic diagram illustrating the physical distortions in tape dimensions, resulting in a bowtie effect, in accordance with the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to the figures and in particular with reference to **Figure 1**, a diagram of a system is

5   illustrated in which the present invention may be implemented. A tape drive system **100** is configured to receive a tape cartridge, such as tape cartridge **102**, which contains a housing with a loop of tape wound on one or more reels in the housing. Tape drive system **100** may

10   be used for a variety of applications. For example, tape drive system **100** may be used as a stand-alone unit within a computer to provide backup. Additionally, tape drive system **100** also may be used within a robotic tape cartridge handling system to receive tape cartridges

15   handled by robotic arms. In such a case, tape drive system **100** is a stand-alone system in which a separate controller is present for handling the accessing of tapes. Information may be retrieved from such a system for use by a computer.

20   In this example, the tape in tape cartridge **102** contains servo control information located in tracks on the tape. Typically, this information is a repeating servo pattern of magnetic flux transitions. Alternatively, optical servo tracks also may be found on

25   the tape. Tape drive system **100** can read servo control information and generate a position signal used to control the position of an associated data read head within tape drive system **100**. Servo control information may be written onto the tracks using a servo write head.

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Tape cartridge **102** may take a variety of formats, such as, for example, 8 mm, 4 mm, ¼ inch, and ½ inch formats.

With reference to **Figure 2A**, a diagram illustrating a tape and servo tracks is depicted that may be used to

5   illustrate principles of the present invention. Tape **200** has a width **202**. For this example, it may be assumed that tape **200** is undistorted (e.g., tape distortion=N=0). Tape **200** includes data stripes **204**, **206**, **208**, **210** in which one or more data tracks are located. Also, servo

10   tracks **212**, **214**, **216**, **218**, **220** are found on tape **200**. As illustrated, servo tracks **212**, **214**, **216**, **218**, **220** are magnetic tracks, but may take other forms, such as, for example, optical tracks. In this example, five servo tracks are shown for purposes of illustrating the

15   principles of the present invention. Depending on the implementation, other numbers of servo tracks may be found.

Servo read elements **222**, **224** are located within head **230.** These servo read elements or transducers, also

20   referred to as "servo read heads" or "servo readers", are found within read/write head assembly **230** in this example. Also, in this example, data read/write elements or transducers **226**, **228** are found within read/write head assembly **230**. Data read/write elements **226**, **228** are

25   positioned over data stripes **204**, **210**, respectively.

Servo readers **222**, **224** are positioned over servo tracks **212**, **220** in this example. Note, within the principles of the present invention, that the terms "positioned, positioning, positioned, position" may be

30   defined to include an operation of acquiring a track

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and/or following a track. Also, for illustrative
purposes, servo readers **222**, **224** are shown positioned
over outermost servo tracks **212**, **220**. However, the
present invention is not intended to be so limited, and
5   the servo readers used (e.g., **222**, **224**) may be positioned
over any servo tracks or combination of servo tracks on
the tape used (e.g., **200**).

These servo tracks may employ various patterns or
frequency regions to allow precise tape-to-tape head
10   positioning to allow for more accurate access of data
from data tracks. The servo control system in a tape
drive generates a position error signal based on
differences in signal amplitudes generated by servo
readers **222**, **224**. Also, signal phase or timing
15   difference data may be used to generate a position error
signal. The position error signal is used to align
read/write head assembly **230** with tape **200**.

Essentially, **Figure 2A** illustrates an accurate
alignment of read/write head assembly **230** with an
20   undistorted tape (e.g., N=0). In this example, it may be
assumed that both servo readers **222**, **224** are operable and
accurately tracking their respective servo tracks **212**,
220. Consequently, with undistorted tape **200**, both data
read/write elements **226**, **228** are accurately positioned
25   over their respective data stripes **204**, **210**. In this
case, no positioning compensation for tape distortion has
to be applied.

With reference now to **Figure 2B**, another diagram
illustrating a tape and servo tracks is depicted that may
30   be used to illustrate principles of the present

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invention. Again, it may be assumed that tape **200** is undistorted (e.g., N=0) and has width **202**. However, for this example, it may be assumed that (upper) servo reader **222** is operable, and (lower) servo reader **224** is

5   inoperable (e.g., as indicated by the cross-hatched lines). Notably, although servo reader **224** is inoperable, servo reader **222** is still operable and can accurately follow its servo track **212**. Consequently, as illustrated by **Figure 2B**, with an undistorted tape and

10 one inoperable servo reader, data read/write elements **226, 228** can still be accurately positioned over data stripes **204, 210**.

　　With reference now to **Figure 2C**, another diagram illustrating a tape and servo tracks is depicted that may

15 be used to illustrate principles of the present invention. Again, it may be assumed that tape **200** is undistorted (e.g., N=0) and has width **202**. However, for this example, it may be assumed that (lower) servo reader **224** is operable, and (upper) servo reader **222** is

20 inoperable (e.g., as indicated by the cross-hatched lines). Note, in this case, that although servo reader **222** is inoperable, servo reader **224** is still operable and can accurately track its servo track **220**. Once again, as illustrated by **Figure 2C**, with an undistorted tape and

25 one inoperable servo reader, data read/write elements **226, 228** can still be accurately positioned over data stripes **204, 210**.

　　With reference now to **Figure 3A**, a diagram illustrating a tape and servo tracks is depicted that may

30 be used to illustrate principles of the present

invention. For this example, it may be assumed that tape
300 is distorted (e.g., tape distortion=N). Possibly,
the tape has stretched over a period of time and,
therefore, the width of the tape has decreased. In other
5   words, tape 300 is narrower than tape 200 by an amount,
N. As such, in this illustrative example, tape 300 has
width 302 that is equal to width 202 of tape 200 in
Figures 2A-2C minus the tape distortion value, N.

Tape 300 includes data stripes 304, 306, 308, 310 in
10 which one or more data tracks are located. Also, servo
tracks 312, 314, 316, 318, 320 are found on tape 300. As
illustrated, servo tracks 312, 314, 316, 318, 320 are
magnetic tracks, but may take other forms, such as, for
example, optical tracks. In this example, five servo
15 tracks are shown for purposes of illustrating principles
of the present invention. Depending on the particular
implementation involved, other numbers of servo tracks
may be found.

Servo readers 322, 324 are found within read/write
20 head assembly 330 in this example. Also, data read/write
elements 326, 328 are found within read/write head
assembly 330. Again, it may be assumed that tape 300 is
distorted. Additionally, for this illustrative example,
it may be assumed that both (upper) servo reader 322 and
25 (lower) servo reader 324 are operable.

Note that with tape distortion and operable servo
readers, data read/write elements 326, 328 can be
positioned at their optimal read/write positions over
data stripes 304, 310 using an offset of N/2. As such,
30 the probability of data loss is relatively low for both

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read/write elements **326**, **328** because of their optimal
positioning over data stripes **304**, **310**.

5   However, **Figure 3A** also illustrates that existing
track following servo systems are unable to attain
optimum positioning with tape distortion and only one
operable servo reader. Furthermore, **Figure 3A**
illustrates that with only one operable servo reader,
even if existing track following servo systems are
somehow able to attain optimum track positioning with

10   tape distortion, as the amount of tape distortion
continues to change over time, the existing track
following servo systems are unable to continue to
determine and maintain an optimum track position from
then on. As described below with respect to **Figure 3D**,

15   the present invention resolves this problem, and
positioning compensation with tape distortion and an
inoperable servo reader may be applied.

With reference now to **Figure 3B**, a diagram
illustrating a tape and servo tracks is depicted that may

20   be used to illustrate principles of the present
invention. For this example, again it may be assumed
that tape **300** is distorted (e.g., tape distortion=N). In
other words, tape **300** is narrower than tape **200** by the
amount, N. Also, in this illustrative example, tape **300**

25   has width **302** that is equal to width **202** of tape **200** in
Figures 2A-2C minus the tape distortion value, N.

Tape **300** includes data stripes **304**, **306**, **308**, **310** in
which one or more data tracks are located. Also, servo
tracks **312**, **314**, **316**, **318**, **320** are found on tape **300**. As

30   illustrated, servo tracks **312**, **314**, **316**, **318**, **320** are

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magnetic tracks, but may take other forms, such as, for example, optical tracks.

Servo readers **322**, **324** are found within read/write head assembly **330** in this example. Also, data read/write

5 elements **326**, **328** are found within read/write head assembly **330**. Again, it may be assumed that tape **300** is distorted. Additionally, for this example, it may be assumed that (upper) servo reader **322** is operable, but (lower) servo reader **324** is inoperable (e.g., as

10 indicated by the cross-hatched lines).

Note that with tape distortion and an inoperable servo reader, that although servo reader **322** is operable and can accurately follow its servo track **312**, data read/write elements **326**, **328** are not accurately

15 positioned over data stripes **304**, **310**. In fact, data read/write elements **326**, **328** are offset from their optimal read/write positions over data stripes **304**, **310** by a factor of N/2 (e.g., with respect to the optimum position illustrated in **Figure 3A**). As such, the

20 probability of data loss is relatively high for read/write element **326**, because of it's offset (e.g., N/2) from the optimal position over data stripe **304**, and possible signal interference from servo track **314**. Furthermore, the probability that data will be lost is

25 guaranteed for read/write element **328**, because of it's offset (e.g., N/2) and positioning over servo track **320**. In accordance with the present invention, and as described below with respect to **Figure 3D**, positioning compensation for the tape distortion can be applied.

With reference now to **Figure 3C**, a diagram
illustrating a tape and servo tracks is depicted that may
be used to illustrate principles of the present
invention. For this example, again it may be assumed
5   that tape **300** is distorted (e.g., tape distortion=N).
Therefore, tape **300** has width **302** equal to that of tape
200 in **Figures 2A-2C** minus N. Additionally, for this
example, it may now be assumed that (lower) servo reader
324 is operable, and (upper) servo reader **322** is
10   inoperable (e.g., as indicated by the cross-hatched
lines).

Note once again, with tape distortion and an
inoperable servo reader, that although servo reader **324**
is operable and can accurately follow its servo track
15   **320**, data read/write elements **326**, **328** are again not
accurately positioned over data stripes **304**, **310**. In
fact, data read/write elements **326**, **328** are offset from
their optimal read/write positions over data stripes **304**,
310 by a factor of N/2 (e.g., with respect to the optimum
20   position illustrated in **Figure 3A**). As such, the
probability of data loss is relatively high for
read/write element **328**, because of it's offset (e.g.,
N/2) from the optimal position over data stripe **310**, and
possible signal interference from servo track **318**.
25   Furthermore, the probability that data will be lost is
guaranteed for read/write element **326**, because of it's
offset (e.g., N/2) and positioning over servo track **312**.
In accordance with the present invention, and as
described below with respect to **Figure 3D**, positioning
30   compensation for the tape distortion can be applied.

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With reference now to **Figure 3D**, a diagram
illustrating a tape and servo tracks is depicted in
accordance with a preferred embodiment of the present
invention. For this example, again it may be assumed

5   that tape **300** is distorted (e.g., tape distortion=N).
Therefore, tape **300** has width **302** equal to that of tape
200 in **Figures 2A-2C** minus N. Additionally, for this
example, it may now be assumed that (upper) servo reader
322 is operable, and (lower) servo reader **324** is

10   inoperable (e.g., as indicated by the cross-hatched
lines). As an alternative, in accordance with the
present invention, the lower servo reader could be
operable, and the upper servo reader could be inoperable.
The particular arrangement and/or number of operable and

15   inoperable servo readers are not intended as
architectural limitations for the present invention. The
principles of the present invention may be applied as
well for tape drives using more than two servo readers
for positioning one or more data read/write heads.

20   Essentially, in accordance with a preferred
embodiment of the present invention, a track following
servo system can compensate for an inoperable servo
reader (e.g., **324**) by collecting and measuring tape
distortion information from the tape involved. The track

25   following servo system can quantify the tape distortion
information and produce a tracking offset value. The
track following servo system can position the operable
servo reader over the tape with the compensating offset
value applied. Consequently, the tracking offset for the

data read/write elements and probability of data loss are minimized.

For this exemplary embodiment illustrated in **Figure 3D**, a track following servo system (not shown) can use

5 one or more operable servo readers (e.g., **322** and/or **324**) to collect tape distortion information over a period of time. For example, if both servo readers **322**, **324** are operable (e.g., prior to a servo reader failure), during one or more initial passes of tape **300** under read/write

10 head assembly **330**, each servo reader **322**, **324** can read servo tracking information from its respective servo track **312**, **320**. The track following servo system can quantify and store the servo tracking information received.

15 As tape **300** becomes more and more distorted over a period of time (e.g., N is increasing), the positioning errors for servo readers **322**, **324** are increasing over the same period of time. The track following system can calculate a track following compensating offset value

20 based on the historical positioning error information received. Thus, if a servo reader (e.g., **324** in this example) fails or has failed, then the track following servo system can position an operable servo reader (e.g., **322**) over tape **300** with the track following compensating

25 offset value applied.

For this example, it may be assumed that (lower) servo reader **324** becomes inoperable sometime after the initial pass or passes are performed. Also, it may be assumed that the track following servo system has used

30 the received historical positioning error information to

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quantify and store information representing the tape
distortion, N, for tape **300**. The track following servo
system can minimize the effects of the tracking offsets
due to tape distortion, N, for data read/write elements
5   **326**, **328**, by positioning operable servo reader **322** over
tape **300** with a compensating offset value of N/2 (e.g.,
with respect to the optimum position illustrated in
Figure 3A). Advantageously, using a compensating offset
value of N/2, the track following servo system can mimic
10   a track following operation with tape distortion involved
(e.g., as illustrated in **Figure 3A**), which averages track
following measurement information received from two
operable servo readers. At this point, it is important
to note that although an exemplary compensating offset
15   value of N/2 has been described herein for illustrative
purposes, the present invention is not intended to be so
limited. In accordance with principles of the present
invention, any appropriate compensating offset value can
be used for optimum positioning of an operable servo
20   reader over a tape with an inoperable servo reader and
tape distortion involved.

    In accordance with the present invention, a number
of techniques may be used to measure and quantify tape
distortion. For example, a second read/write head
25   assembly with two operable servo readers may be used to
read servo tracks **312**, **320** or other servo tracks (e.g.,
314, **318**). The resulting tape distortion information can
be used to position the operable servo reader of the
first read/write head assembly over tape **300** with the
30   compensating offset value (e.g., N/2) applied.

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As another example, a second bump (e.g., read bump, write bump) with two operable servo readers arranged on read/write head assembly **330** may be used for measuring and quantifying tape distortion of tape **300**. The tape

5   distortion information thus derived may be used to position the operable servo reader of the first bump over tape **300** with the compensating offset value (e.g., N/2) applied.

As still another example, a sensor may be arranged

10   in proximity to one or more edges of tape **300**. As tape **300** becomes distorted over time, the edge sensor(s) can generate an analog signal over time whose magnitude represents the increasing distance between the sensor and the edge of the tape (e.g., tape distortion). Again, the

15   resulting tape distortion information can be used to position the operable servo reader of read/write head assembly **330** over tape **300** with the compensating offset value (e.g., N/2) applied.

Additionally, a mathematical model that can predict

20   tape distortion as a function of the age, use and/or position of the tape involved may be used to derive tape distortion. Also, tape distortion may be inferred from bit error rates (BERs) of individual data read/write elements. For example, as the width of a tape decreases,

25   the BERs of data read/write elements typically increase.

Notably, in accordance with a preferred embodiment of the present invention, a plurality of servo readers may be used to collect component position error signal (PES) data from servo tracks on the tape involved. The

30   separate PES data can be analyzed to determine tape

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distortion (e.g., N). The data can also be adjusted for reliability factors that might affect the confidence of the PES data. The distortion data for the tape can then be used to derive a compensating offset value (e.g., N/2)

5   to be applied for positioning an operable servo reader over the tape involved.

In order to collect PES data from a tape, referring now to **Figure 4**, a diagram of servo position errors due to displacement of servo tracks is depicted in accordance

10   with a preferred embodiment of the present invention. In **Figure 4**, the exemplary graph shows position error for a three-servo track tape drive system in a two-reel cartridge. In **Figure 4**, line **400** represents data generated by an upper servo reader, line **402** illustrates

15   data generated by a mid-position servo reader, and line **404** shows data generated by a lower servo reader. The tape, in this example, is located in a dual reel cartridge.

Lines **400**, **402**, and **404** illustrate servo position

20   errors due to displacement on a tape. The vertical axis indicates the amount of position or displacement error. Various units may be used, such as micrometers, micro-inches, or volts depending on the measurement made. The magnitude of the vertical axis varies depending on

25   factors, such as, for example, the size of the cartridge and the reels, the materials used, and the dimensions of the tape. The horizontal axis identifies the longitudinal position.

Specifically, the longitudinal position is an

30   arbitrary, but fixed, measure of the physical locations

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lengthwise on the tape. The graph in **Figure 4**
illustrates typical servo position error for a three-
servo track system in a two-reel cartridge. The
beginning of each line at vertical line **406** represents

5   the beginning or one end of the tape. Vertical line **408**
represents the other end of the tape, while the vertical
line **410** represents the middle of the tape. The
symmetrical nature of the graph in **Figure 4** stems from
the fact that equal amounts of tape are normally stored

10   on each of the two reels. If, on the other hand, the
tape is normally stored on one of the two reels, the
profile will eventually approach the shape of either the
left or right half of **Figure 4** depending upon which reel
the tape is stored. The time constant of this change

15   will depend on a variety of factors, such as environment,
usage, spool size, and tape type.
In reading a tape (e.g., tape **300** in **Figure 3D**), the
middle servo track is positioned directly under a
particular servo read element. The upper servo track and

20   the lower servo track are not aligned with the upper and
lower servo readers except at crossover points **412** and
414 in **Figure 4**. In **Figure 4**, the illustrated signals
are the inverse of the actual tape dimensions. These
three lines illustrate a "bowtie" or "lips" effect, which

25   is repeatable and predictable for a two-reel cartridge as
the tape is played from one end to the other end.
In **Figure 4**, although the tape is servo-written in a
very controlled, parallel manner on the tape, compression
and tension forces in the cartridge change the dimensions

30   of this tape. In other words, in many cases the servo

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tracks written onto the tape from a large spool in which
a length of tape is then placed on a reel in a cartridge.
Servo tracks are written before spooling the tape onto a
cartridge out of convenience so as to define the
5   locations of the servo tracks in a very precise manner.
Data is then written by a customer, and the data tracks
are referenced in location to the servo tracks to
uniquely define the positions of the data tracks.

     Referring now to **Figure 5**, a schematic diagram
10   illustrating compressive and tangential forces on a tape
wrapped onto two spools is depicted in accordance with
the present invention. When tape is wound around a reel,
compressive forces tend to press out or increase the
width of the tape. Compressive forces vary with position
15   in the tape pack. These compressive forces, also
referred to as radial forces, are decreased or removed
when the tape is unwound from the reel. Although the
compressive forces that cause the tape to widen are
removed when the tape is unwound, the dimensional width
20   change is residual. Tension and tangential forces also
are present. These forces stretch the tape and cause the
tape to become narrower. The interaction between the
radial compressive and tangential, tensile forces give
rise to the long-term dimensional variations of spooled
25   tape. As a result of the different forces applied to the
tape, the width of the tape will change. These types of
forces result in dimensional variations in the tape and
thus, track to element displacements as shown by the
servo position error signals illustrated in lines **400**,
30   **402**, and **404** in **Figure 4**.

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Referring to **Figure 6**, a schematic diagram
illustrating the physical distortions in tape dimensions,
resulting in a bowtie effect, is depicted in accordance
with the present invention. **Figure 6** shows three servo
5   readers **601-603** positioned over three servo tracks **604-
606**. The upper servo reader **601** detects a roof shaped
PES curve over the length of the tape, meaning the PES
608 is positive at center of tape (COT) **607**. Since the
tape head **600** is a solid, stable reference frame, the
10   servo track **605** is low in relation to the upper servo
reader **601**. The opposite is true with the lower reader
603 and servo track **606**. Therefore, the servo tracks **605**
and **606** are distorted and the tape is narrower at COT **607**
than at the ends. PES data **608** quantifies how much tape
15   distortion (e.g., N) there is.

The present invention can be implemented as a
software change to a tape drive servo system. For this
exemplary embodiment, the present invention can collect,
filter, compress, store and process component PES data in
20   order to infer some of the physical characteristics of
the tape. Thus, with this and the other above-described
techniques, the track following system can measure and
quantify the amount of tape distortion involved, and
produce a tracking offset value. The track following
25   servo system can then position an operable servo reader
over the tape with the compensating offset value applied.

It is important to note that while the present
invention has been described in the context of a fully
functioning data processing system, those of ordinary
30   skill in the art will appreciate that the processes of

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the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention applies equally regardless of the particular type of

5   signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media such a floppy disc, a hard disk drive, a RAM, CD-ROMs, and transmission-type media such as digital and analog communications links.

10   The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in

15   the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are

20   suited to the particular use contemplated.